RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING
e-ISSN: 2773-4765

RPMME

Vol. 6 No. 2 (2025) 40-49
https://publisher.uthm.edu.my/periodicals/index.php/rpmme

Innovative Redesign of an Umbrella Using Quality Function Deployment (QFD) and Theory of Inventive Problem Solving (TRIZ)

Muhammad Zakwan Yahaya[1], Musli Mohammad[1]*

[1] *Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia*

*Corresponding Author: mmusli@uthm.edu.my
DOI: https://doi.org/10.30880/rpmme.2025.06.02.005

Article Info

Received: 31 July 2025
Accepted: 31 October 2025
Available online: 10 Disember 2025

Keywords

Quality Function Deployment (QFD), Theory of Inventive Problem Solving (TRIZ), House of Quality (HOQ), umbrella design, Customer Requirements, Product Improvement

Abstract

Umbrellas are essential tools for weather protection, yet many existing designs lack portability, ease of use, and adequate coverage; particularly for university students who require compact, reliable, and user-friendly solutions for daily mobility. One of the most critical issues identified is the need for umbrellas that are lightweight and foldable for easy carrying and storage, especially in backpacks or bags. The objectives of this project are to identify customer requirements for umbrellas, evaluate the importance of these requirements and the performance of existing umbrella designs, and propose design improvement using the Quality Function Deployment (QFD) and Theory of Inventive Problem Solving (TRIZ) methods. Data were collected through pilot interviews and a questionnaire survey involving 100 university students to capture users' requirements. Based on the survey analysis, the top three prioritized customer requirements were: (1) lightweight and foldable for easy carrying and storage, (2) smooth operation, and (3) sufficient coverage to keep users and their belongings dry. The integration of QFD and TRIZ effectively translated the user requirements into technical specifications and guided innovation in the design process. As a result, a new umbrella concept was proposed, featuring a head-mounted design for hands-free operation and full coverage, along with lightweight materials and an enhanced opening mechanism. The final design was developed using SolidWorks software. This study demonstrates that combining QFD and TRIZ offers a structured and effective approach to user-centered product innovation.

1. Introduction

Umbrellas are essential tools for personal protection against sun and rain. However, traditional umbrella designs often fail to meet modern expectations in terms of durability, strength, and user comfort [1]. Many users experience frustration with umbrellas that are too heavy, not wind-resistant, or break easily after a few uses [2]. Moreover, increased environmental awareness has driven demand for products made from recyclable and sustainable materials [3].

To respond to these challenges, engineering tools such as Quality Function Deployment (QFD) and the Theory of Inventive Problem Solving (TRIZ) have become effective approaches in modern product development [4]. QFD is used to translate the voice of customers into technical specifications, while TRIZ helps resolve design conflicts and find innovative solutions [5].

Studies have shown that combining QFD and TRIZ supports the development of high-performance, customer-oriented products across industries, from cookware handles to electronic tools [6]. However, applications in umbrella design remain limited. This project apply QFD and TRIZ to develop an umbrella design that is lightweight, durable, easy to use, and environmentally friendly [7]. Despite being widely used, many umbrellas in the market are still susceptible to performance issues. They often break under high wind pressure, are not user-friendly, and are made with materials that are not recyclable or long-lasting. Additionally, the existing umbrella designs are not sufficiently aligned with modern consumers' evolving needs, including portability, ease of use, and eco-consciousness. For example, users especially students often struggle with bulky or heavy umbrellas that are difficult to store in backpacks and inconvenient to carry during daily commutes. These limitations indicate a gap in the market for a more efficient, durable, and sustainable umbrella solution.
Umbrella design has evolved significantly in recent years, yet most improvements still lack a comprehensive approach integrating user feedback and systematic design methods [8].

Traditional design adjustments often overlook essential criteria like durability, weight, and portability [9]. QFD has been recognized as a structured technique to embed customer requirements into the early stages of product design [10]. Its application in the manufacturing sector allows translation of voice-of-customer (VOC) into prioritized engineering characteristics [11]. TRIZ, on the other hand, provides innovative direction to resolve technical contradictions that commonly occur in consumer product development [12]. For instance, TRIZ has been applied to enhance lightweight but durable solutions in mobility tools [13], and in household product designs requiring collapsibility and ergonomic usability [14]. Some research has demonstrated that combining QFD and TRIZ can significantly reduce material waste and improve product lifecycle [15]. More recent applications include designs for medical devices and portable equipment where low weight and ease of handling are critical [16]. These cases highlight the versatility of QFD and TRIZ in various product domains, showing promising potential for umbrella enhancement [17]. Additionally, the benefit of integrating CAD and TRIZ to bridge technical requirements with customer needs in product design has been established [18]. A review of umbrella product improvements highlights user-centred demand trends [19]. Finally, the use of validated questionnaires ensures accurate and reliable survey data [20]. This project aims to identify and prioritize customer requirements for umbrella design, evaluate the performance of existing umbrella products against these requirements and propose a new umbrella design using the QFD and TRIZ methodologies.

2. Methodology

The method and process flow were explained briefly and followed by data collection. An appropriate approach has been selected and properly planned to meet the objectives of this study.

2.1 Data Collection

A pilot interview with five umbrella users was conducted to explore common issues. Insights gained were used to construct a structured questionnaire, guided by Garvin's 8 Dimensions of Product Quality. The final survey involved 100 respondents at Universiti Tun Hussein Onn Malaysia.

2.2 Research Process Flow

Fig 1 illustrates the sequential process applied in the study, from user input to concept selection.

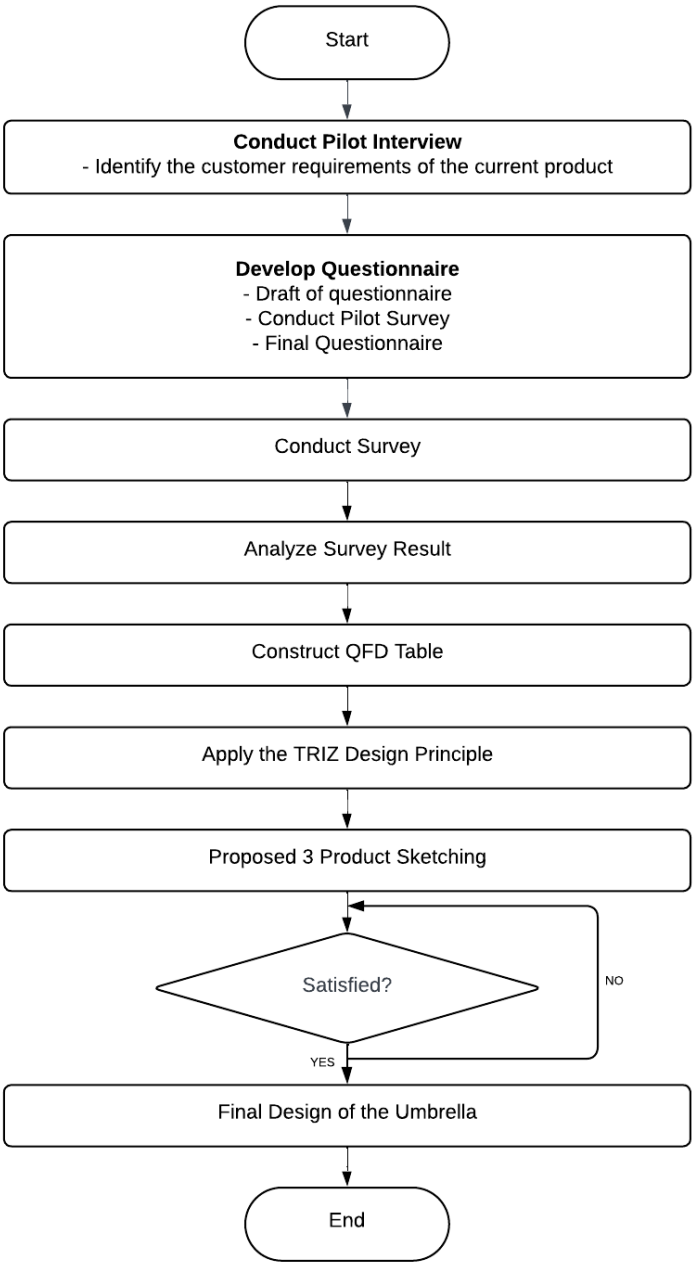


Fig 1 *The flow of the research*

2.3 Quality Function Deployment (QFD) Process

Customer requirements from the survey were translated into technical parameters using the House of Quality. **Table 1** supports this analysis by presenting the mean of each customer requirement along with a comparison of performance scores for two umbrella types: a classic umbrella and a foldable one in **Table 2.**

Table 1 *Importance rating of the customer requirements*

No.	Customer Requirements	Importance Rating (Mean)
1	Lightweight And Foldable For Easy Carrying And Storage.	77.41
2	Operates Smoothly Every Time.	75.83
3	Offers Sufficient Coverage To Keep The User And Their Belongings Dry.	75.47
4	Includes User-Friendly Mechanisms Like Automatic Open And Close.	74.8

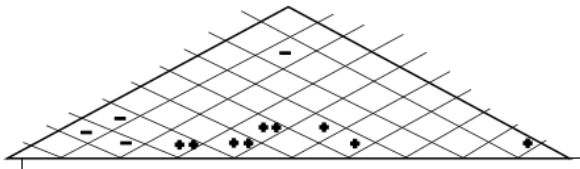
5	Can Withstand Frequent Use Without Breaking Or Tearing.	72.41
6	Made With Materials That Resist Rust And Wear Over Time.	71.54
7	Provides Strong Protection Against Heavy Rain And Wind.	71.18
8	Designed To Last For Several Years Under Normal Usage.	70.26
9	Additional Functionalities Such As Wind Resistance Or Uv Protection.	70.07
10	Effectively Shields Against Uv Rays Or Sunlight.	69.56
11	Stays Intact During Harsh Weather Conditions Like Strong Winds.	67.46
12	Does Not Require Frequent Repairs Or Adjustments	64.28

Table 2 T*he performance of the current umbrella*

No.	Customer Requirements	Performance Rating(Mean)	
		Classic Umbrella (26 Respondents)	Foldable Umbrella (74 Respondents)
1	Lightweight and foldable for easy carrying and storage.	58.75	70.48
2	Operates smoothly every time.	60.58	63.79
3	Offers sufficient coverage to keep the user and their belongings dry.	64.1	66.51
4	Includes user-friendly mechanisms like automatic open and close.	58.83	66.88
5	Can withstand frequent use without breaking or tearing.	60.53	63.03
6	Made with materials that resist rust and wear over time.	60.81	63.45
7	Provides strong protection against heavy rain and wind.	60.33	64.14
8	Designed to last for several years under normal usage.	62.25	64.06
9	Additional functionalities such as wind resistance or UV protection.	59.43	63.61
10	Effectively shields against UV rays or sunlight.	60.77	65.05
11	Stays intact during harsh weather conditions like strong winds.	58.64	63.06
12	Does not require frequent repairs or adjustments	57.8	60.29

2.4 House of Quality (HOQ)

To effectively translate customer requirements into technical responses, the House of Quality (HOQ) matrix was developed using data from the QFD process. The HOQ helped prioritize engineering characteristics based on customer needs identified in the survey and pilot interviews. **Fig 2** shows the HOQ constructed for this study.



Correlation Symbol
Strongly Positive =
Positive =
Negative =
Strongly Negative =

Interrelationship Symbols
Strong = ●
Medium = ■
Weak = ▲

			Technical Requirements										Competitive Evaluation		Quality Planning				
No	Customer Requirements	Importance (A)	Weight of moving object	Length of stationary object	Stability of object	Strength	Durability of moving object	Durability of stationary object	Reliability	Harmful factor acting on object	Convenience of use	Level of automation	Research Focus (FU) [B]	Competing Product (CU)	Target for New Model (C)	Improvement Ratio (D)	Strength (E)	Absolute Wight (F)	Relative Weight (%)
1	Lightweight and foldable for easy carrying and storage.	5	●								■		5	2	5	1	1.5	7.5	8.65
2	Operates smoothly every time	5									●		2	3	5	2.5	1.5	18.8	21.68
3	Offers sufficient coverage to keep the user and their belongings dry.	5	▲	●							■		4	5	5	1	1.5	7.5	8.65
4	Includes user-friendly mechanisms like automatic open and close.	4	▲								■	●	4	1	5	1.25	1.2	6	6.92
5	Can withstand frequent use without breaking or tearing.	4	▲		●	●	●	●	■				2	3	4	2	1.2	9.6	11.07
6	Made with materials that resist rust and wear over time.	3				■		●		▲			2	3	4	2	1.2	7.2	8.3
7	Provides strong protection against heavy rain and wind.	3	▲		●	●	●	●	■				2	2	4	2	1.2	7.2	8.3
8	Designed to last for several years under normal usage.	3	▲			●	●	●	■				2	3	4	2	1.2	7.2	8.3
9	Additional functionalities such as wind resistance or UV protection.	3	▲								■		2	3	4	2	1.2	7.2	8.3
10	Effectively shields against UV rays or sunlight.	2	▲								■		3	3	4	1.25	1.0	2.5	2.88
11	Stays intact during harsh weather conditions like strong winds.	2	▲		●	●	●	●	■				2	1	3	1.5	1.0	3	3.46
12	Does not require frequent repairs or adjustments.	1	●				■	■	●				1	1	3	3	1.0	3	3.46
	Raw Score		80	45	81	117	111	138	45	3	102	36	758			Total		86.7	100
	Relative Weight (%)		10.55	5.94	10.69	15.44	14.64	18.21	5.94	0.4	13.46	4.75	100						
	Rank Order		6	8	5	2	3	1	7	10	4	9	Total						

Fig 2 *House of Quality (HOQ) of the umbrella*

2.5 Theory of Inventive Problem Solving (TRIZ) Integration

Using TRIZ's 39 engineering parameters and contradiction matrix, technical conflicts were resolved. To resolve technical conflicts identified through QFD, TRIZ tools were applied. **Table 3** summarizes the relevant engineering parameters and contradiction pairs, along with the TRIZ principles suggested to overcome them.

Table 3 *The technical parameters of TRIZ for the product improvement*

Undesired Result (Conflict) / Feature to Improve		1 Weight of moving object	4 Length of stationary object	13 Stability of object	14 Strength	15 Durability of moving object	16 Durability of stationary object	27 Reliability	30 Harmful factor acting on object	33 Convenience of use	38 Level of automation
1	Weight of moving object		1,10,35	1,28, 34	2,13, 18	2,26, 18	1,35, 18	2,26, 18		1,15,35	1,28,35
4	Length of	1,10,35		3,15,	8,13,35	2,13,26	2,13,35	1,13,26		1,28,35	1,28,35

Research Progress in Mechanical and Manufacturing Engineering Vol.6 No. 2 (2025) p. 40-49

	stationary object			29							
13	Stability of object	1,28, 34	3,15, 29		2,13,24	2,13,35	13,24,35	13,24,35	10,13,35	13,28,35	13,28,35
14	Strength	2,13, 18	8,13,35	2,13,24		2,13,24	13,24, 18	13,24,35		13,28,35	13,28,35
15	Durability of moving object	2,26, 18	2,13,26	2,13,35	2,13,24		13,24,35	13,24,35		13,28,35	13,28,35
16	Durability of stationary object	1,35 18	2,13,35	13,24,35	13,24, 18	13,24,35		13,24,35		13,28,35	13,28,35
27	Reliability	2,26, 18	1,13,26	13,24,35	13,24,35	13,24,35	13,24,35			13,28,35	13,28,35
30	Harmful factor acting on object			10,13,35	10,13,35	10,13,35	10,13,35	10,13,35		10,13,35	10,13,35
33	Convenience of use	1,15,35	1,28,35	13,28,35	13,28,35	13,28,35	13,28,35	13,28,35			13,28,35
38	Level of automation	1,28,35	1,28,35	13,28,35	13,28,35	13,28,35	13,28,35	13,28,35	10,13,35	13,28,35	

3. Results and Discussion

This section presents the outcome of the analysis based on survey data, QFD prioritization, and the application of TRIZ principles in addressing the identified technical contradictions. The results highlight how customer expectations guided the improvement of umbrella design, while the discussion elaborates on how each design decision contributes to enhanced performance and user satisfaction.

3.1 Analysis of Customer Needs

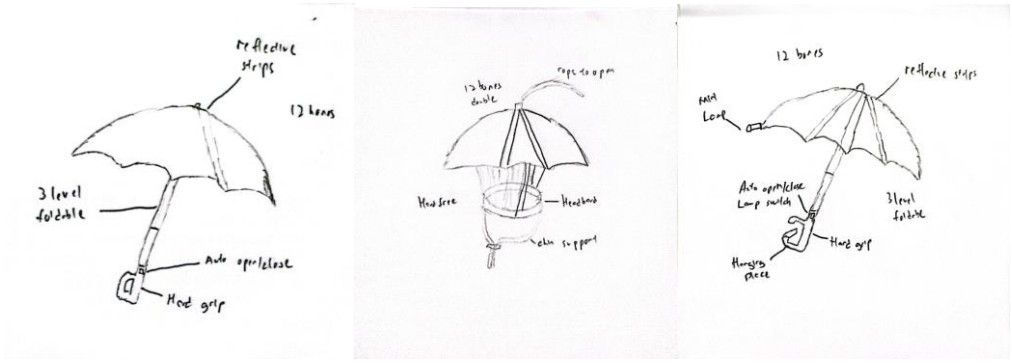
Survey results from 100 respondents at Universiti Tun Hussein Onn Malaysia were analyzed using Garvin's 8 Dimensions of Product Quality. The most important customer needs identified were waterproofing, lightweight design, durability, and smooth automatic operation. Users also preferred umbrellas made from eco-friendly materials. This information guided the development of the QFD matrix, helping to translate user needs into technical improvements.

3.2 Application of QFD and TRIZ

Using the House of Quality, customer requirements were translated into technical specifications. Features such as "lightweight frame," "corrosion-resistant materials," and "automated mechanisms" were prioritized. **Table 1** and **Table 2** supported this prioritization by comparing classic and foldable umbrellas. Using TRIZ principles (Composite Materials**,** Segmentation**,** and Preliminary Action), design contradictions like "lightweight vs. durability" were resolved innovatively.

3.3 Concept Development and Evaluation

Based on the QFD and TRIZ analysis, three concept designs were developed to address customer needs such as light weight, durability, and ease of use. These sketches are shown in Fig 3 (a–c).



(a) **(b)** **(c)**

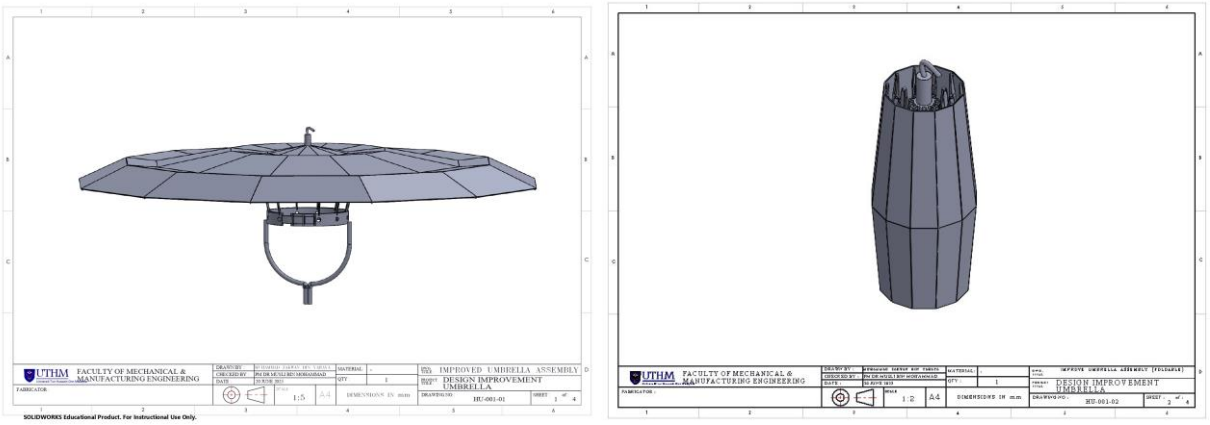
Fig. 3 *Proposed product improvement (a) Sketch A; (b) Sketch B; (c) Sketch C*

Three design sketches were developed to reflect the integration of QFD and TRIZ outputs. These concepts addressed customer pain points, especially:

- **Concept A**: Focused on wind resistance using a dual-layer canopy.
- **Concept B**: Emphasized portability using segmented, collapsible shafts, and hand-free.
- **Concept C**: Introduced reflective and sustainable materials for visibility and eco-friendliness.

3.4 Final Design Features

After evaluating all three concepts, the final design was selected for further development. The improved umbrella includes a reverse folding system, ergonomic handle, and lightweight frame. Fig 4 (a–b) shows the final umbrella design in both open and closed positions.



(a) **(b)**

Fig. 4 *Final design (a) Open; (b) Close*

Based on evaluations, a final umbrella design was proposed with the following improvements:

- Reverse folding mechanism to prevent dripping and improve usability.
- Polypropylene plastic ribs and polycarbonate fabric for strength and durability.
- Innovative top-pull rope system, open easily, more intuitive. Pull-rope mechanism offer smoother, low-resistance operation
- Double ribs and reinforced joints increase long-term durability. Reinforced ribs and flexible support allow better performance in wind
- Fewer moving parts, retractable rope, and adjustable straps reduce repair need

4. Conclusion

This study successfully demonstrated how the integration of Quality Function Deployment (QFD) and the Theory of Inventive Problem Solving (TRIZ) can enhance product development—specifically in the redesign of an umbrella. Through structured analysis of customer needs and resolution of design contradictions, the final concept achieved notable improvements in weight reduction, durability, strength, and sustainability. The application of QFD allowed precise identification of user priorities, while TRIZ facilitated inventive yet practical solutions. The resulting umbrella concept addresses key user concerns and offers potential for real-world implementation. This approach may also serve as a valuable reference for improving other consumer products in the future.

Acknowledgement

This research was made possible through monetary assistance by Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

All authors confirm contribution to the paper as follows: ***study conception and design, data collection, analysis and interpretation of results and draft manuscript preparation.*** *All authors reviewed the results and approved the final version of the manuscript.*

Appendix A

Table 4 *Rating of the importance and performance product of QFD Matrix*

Customer Requirements	Importance Rating	Performance Rating	
		Classic Umbrella	Foldable Umbrella
Lightweight and foldable for easy carrying and storage.	5	2	5
Operates smoothly every time	5	3	2
Offers sufficient coverage to keep the user and their belongings dry.	5	5	4
Includes user-friendly mechanisms like automatic open and close.	4	1	4
Can withstand frequent use without breaking or tearing.	4	3	2
Made with materials that resist rust and wear over time.	3	3	2
Provides strong protection against heavy rain and wind.	3	2	2
Designed to last for several years under normal usage.	3	4	2
Additional functionalities such as wind resistance or UV protection.	3	3	2
Effectively shields against UV rays or sunlight.	2	3	3
Stays intact during harsh weather conditions like strong winds.	2	1	2
Does not require frequent repairs or adjustments.	1	1	1

References

[1] Adomako, S., Gyensare, M. A., Amankwah-Amoah, J., Akhtar, P., & Hussain, N. (2024). Tackling grand societal challenges: Understanding when and how reverse engineering fosters frugal product innovation in an emerging market. *Journal of Product Innovation Management, 41*(2), 211–235. https://doi.org/10.1111/jpim.12678

[2] Chong, P. L., Ganesan, S., Ng, P. K., & Kong, F. Y. (2022). A TRIZ-Adopted Development of a Compact Experimental Board for the Teaching and Learning of Operational Amplifier with Multiple Circuit Configurations. *Sustainability, 14*(21), 14115. https://doi.org/10.3390/su142114115

[3] Hameed, A. Z., Kandasamy, J., Aravind Raj, S., Baghdadi, M. A., & Shahzad, M. A. (2022). Sustainable Product Development Using FMEA ECQFD TRIZ and Fuzzy TOPSIS. *Sustainability, 14*(21), 14345. https://doi.org/10.3390/su142114345

[4] Al-Dwairi, A., Al-Araidah, O., & Hamasha, S. (2023). An Integrated QFD and TRIZ Methodology for Innovative Product Design. *Designs, 7*(6), 132. https://doi.org/10.3390/designs7060132

[5] Ilevbare, I. M., Probert, D., & Phaal, R. (2013). A review of TRIZ, and its benefits and challenges in practice. *Technovation, 33*(2–3), 30–37. https://doi.org/10.1016/j.technovation.2012.11.003

[6] Budi Utomo, M. F. (2023). Handel Design for Wok Frypan Type Pan. *Jurnal Sains Dan Teknologi Industri, 20*(2), 872. https://doi.org/10.24014/sitekin.v20i2.22289

[7] Du, C., & Jiang, L. (2023). Improved design of transmission device for double-shaft mixers based on TRIZ theory. In Z. Xiong & R. He (Eds.), *International Conference on Artificial Intelligence and Industrial Design (AIID 2022)* (p. 36). SPIE. https://doi.org/10.1117/12.2673129

[8] Chahal, S. (2023). Agile Methodologies for Improved Product Management. *Journal of Business and Strategic Management, 8*(4), 79–94. https://doi.org/10.47941/jbsm.1439

[9] Gao, C., Guo, L., Gao, F., & Yang, B. (2015). Innovation design of medical equipment based on TRIZ. *Technology and Health Care, 23*(s2), S269–S276. https://doi.org/10.3233/THC-150962
[10] Chen, S., Zhang, Y., & Gong, J. (2023). A Systematic Decision-Making Approach for Quality Function Deployment Based on Hesitant Fuzzy Linguistic Term Sets. *Applied Sciences, 13*(24), 13104. https://doi.org/10.3390/app132413104
[11] Čereš, M., Švikruhová, P., Zabojníková, V., & Kapsdorferová, Z. (2023). The role of the QFD method in improving product quality: An example. *12-Th International Conference of Management Sustainability – Security – Quality Book of Proceedings*, 250–257. https://doi.org/10.17512/CUT/9788371939563/40
[12] Ko, Y.-T., Lu, C.-C., & Lee, L.-H. (2016). A Contradiction-Based Approach for Innovative Product Design. *MATEC Web of Conferences, 68*, 05001. https://doi.org/10.1051/matecconf/20166805001
[13] Kaliteevskii, V., Bryksin, M., & Chechurin, L. (2021). TRIZ Application for Digital Product Design and Management (pp. 245–255). https://doi.org/10.1007/978-3-030-86614-3_20
[14] Pratama, M. R. A., Hidayat, H., & Negoro, Y. P. (2024). Analysis Of Service Quality In Early Child Care Services Businesses Using Servqual And Quality Function Deployment. *Jurnal Teknik Industri, 10*(1), 91. https://doi.org/10.24014/jti.v10i1.29547
[15] Lu, S., Guo, Y., Huang, W., & Shen, M. (2022). Product Form Evolutionary Design Integrated with TRIZ Contradiction Matrix. *Mathematical Problems in Engineering, 2022*, 1–12. https://doi.org/10.1155/2022/3844324
[16] Yang, C., Cheng, J., & Wang, X. (2019). Hybrid quality function deployment method for innovative new product design based on the theory of inventive problem solving and Kansei evaluation. *Advances in Mechanical Engineering, 11*(5). https://doi.org/10.1177/1687814019848939
[17] Kang, C. Q., Ng, P. K., & Liew, K. W. (2022). A TRIZ-Integrated Conceptual Design Process of a Smart Lawnmower for Uneven Grassland. *Agronomy, 12*(11), 2728. https://doi.org/10.3390/agronomy12112728
[18] Ullah, A. M. M. S., Sato, M., Watanabe, M., & Rashid, Md. M. (2016). Integrating CAD, TRIZ, and Customer Needs. *International Journal of Automation Technology, 10*(2), 132–143. https://doi.org/10.20965/ijat.2016.p0132
[19] Gao, Y., Tan, Y., & Li, W. (2022). Review of umbrella product enhancements: Market needs and challenges. *Design Research Journal, 29*(3), 110–122. https://doi.org/10.1080/17493634.2022.1812390
[20] Yusoff, M. S. B., Arifin, W. N., & Hadie, S. N. H. (2021). ABC of questionnaire development and validation for survey research. *Education in Medicine Journal, 13*(1), 97–108. https://doi.org/10.21315/EIMJ2021.13.1.10